# “WHY AFFORDABILITY IS A SYSTEMS ENGINEERING METRIC”


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Sunday

# JULY 25

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BY SCOTT ADAMS

**Affordability is that characteristic of a product or service that enables consumers to:**

- Procure it when they need it
- Use it to meet their performance requirements at a level of quality that they demand
- Use it whenever they need it over the expected life span of the product or service
- Procure it for a reasonable cost that falls within their budget for all needed products or services

# AFFORDABILITY

## DoD Defines Affordability as:

**Affordability is the degree to which the life-cycle cost of an acquisition program is in consonance with the long-range investment and force structure plans of the Department of Defense or individual DoD Components. Affordability procedures establish the basis for fostering greater program stability through the assessment of program affordability and the determination of affordability constraints.**

- **Components shall plan programs consistent with the DoD Strategic Plan, and based on realistic projections of likely funding available in the Future Years**

- **Affordability shall be assessed at each milestone decision point beginning with program initiation – usually- MILESTONE 1.**

- **Cost Analysis Improvement Group (CAIG) reviews shall be used to ensure cost data of sufficient accuracy is available to support reasonable judgements on affordability for ACAT 1 programs.**

- **DoD Component Heads shall consult with the USD (A&T) or the ASD(C3I), as appropriate, on program objective memoranda (POM) and budget estimate submissions (BES) that contain a significant change in funding for, or reflect a significant funding change in, any program subject to review by the DAB or the DoD Chief Information Officer.**

# WHY?

## AFFORDABILITY IS A SYSTEMS ENGINEERING METRIC

- **Because affordability is a decision making tool – these methodologies will support selection of the most affordable technologies and systems.**

- **Because affordability can be improved, measured and predicted – these techniques enable analysts to forecast expected affordability of alternative technologies and systems, and to measure improvement in affordability of a given system**

- **Provides a structures analytical path from determining requirements to fielding affordable systems.**

- **Conducting research into the concepts of affordability and methods to implement the approach.**

- **Establishes a foundations for creating Affordability Systems Engineering Science.**

- **Begin studying Complexity Sciences to understand links between fitness and affordability.**

- **Investigation of game theoretical modeling and other advanced Systems Engineering concepts to focus on System thrusts that will leverage significant downstream system affordability.**

- **Initiate research**

# “HOW”

## AFFORDABILITY IS UTILIZED

1. **Determine the customer concerns and understand those concerns**
   - Explicit – States cost goals or operating budgets
   - Implicit – Customer desire to reduce program staffing
   - Next Phase – Contract contains a limited budget/funding
   - Unit Production – Average Unit Production Cost (AUPC) goals
   - Total Ownership Costs (TOC)-Reduced Total Ownership Costs (RTOC)- Life Cycle Costs (LCC) must be some determine percent (normally 30%) less than the replaced system

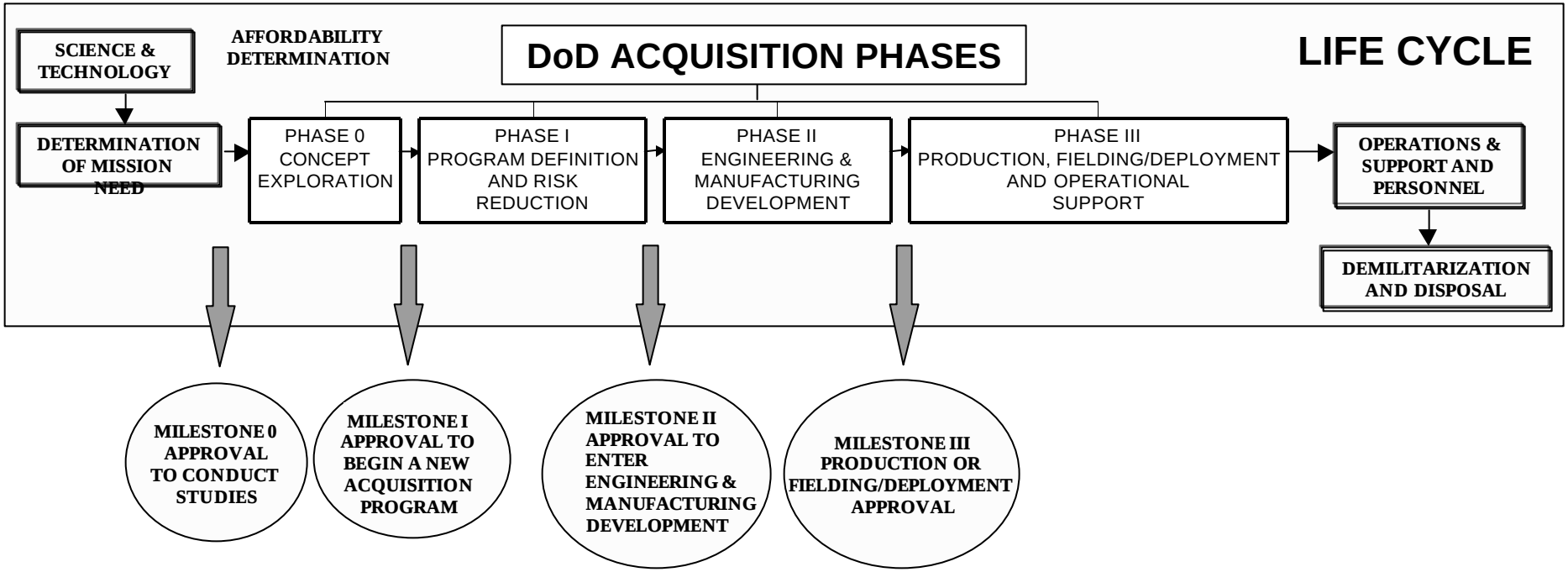
2. **Determine how the competition impacts affordability**
   - Marketing determines cost limit to WIN the contract
   - Existing inventory items with potential modification costs

3. **Set design goals (Including system cost Goals and Targets)**
   - Top level system or architecture
   - Subsystems
   - All phases

4. **Understand system requirements vs. system affordability**
   - Perform the economic analysis
   - Establish a Cost As Independent Variable, Design To Life Cycle Cost or Design To Cost program
   - Systems Engineering Owns all requirements including the cost goals and targets.

5. **Review the present estimates against goals often and react appropriately and expediently**

# ACQUISITION PHASES AND MILESTONES



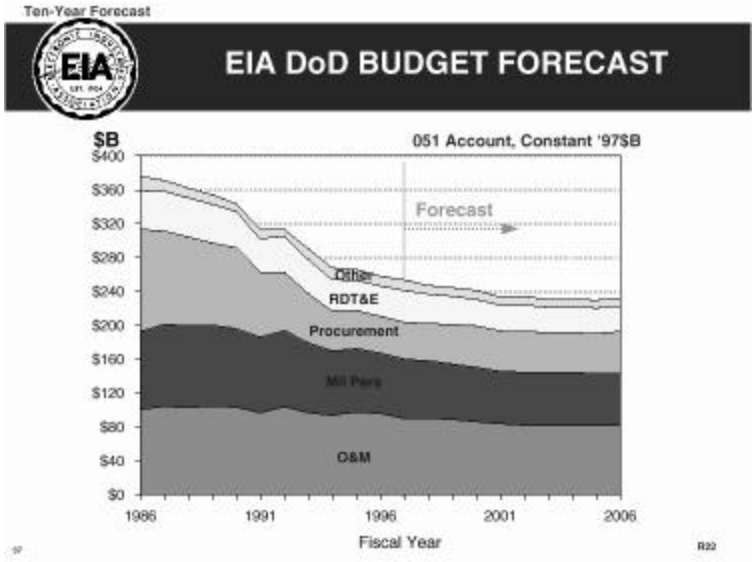

**Program Initiation Documentation:**

| ALL ACATS MS 0 | ACAT I MS I | ACAT II/III/IV MS I |
|---|---|---|
| Mission Need Statement * | Operational Requirements Doc.* | X |
| Sys Threat Assessment Report* | Sys Threat Assessment Report* | X |
| | JROC Assessment* | - |
| | Acquisition Strategy | X |
| | **Program Life Cycle Cost Estimate** | X |
| | Acquisition Program Baseline Agreement | X |
| | Test & Evaluation Master Plan | X |
| | Independent Cost Estimate* | - |
| | Risk Assessment* | X |
| | Analysis of Alternatives* | X |
| | Environmental, Safety, & Health Analysis | X |
| | Cooperative Opportunities Assessment | - |
| | Technology & Industrial Capability Assessment | - |

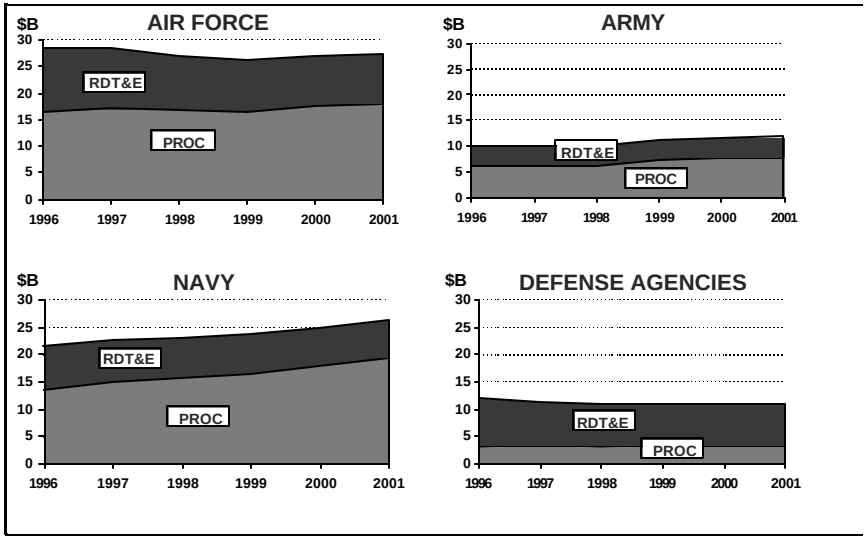
**COST ANALYSIS TERMS:**

- **Life Cycle Cost (LCC) = Program Specific Costs for all phases**
- **Total Ownership Costs (TOC) = LCC + Other Government Costs Associated With the Program**
- **CAIV = A Management Methodology Where a Firm LCC or TOC Limit is Imposed on the Program Design**
- **Affordability = Each Program Phase Costs, LCC and TOC Must Be Within Budgeted Values.**

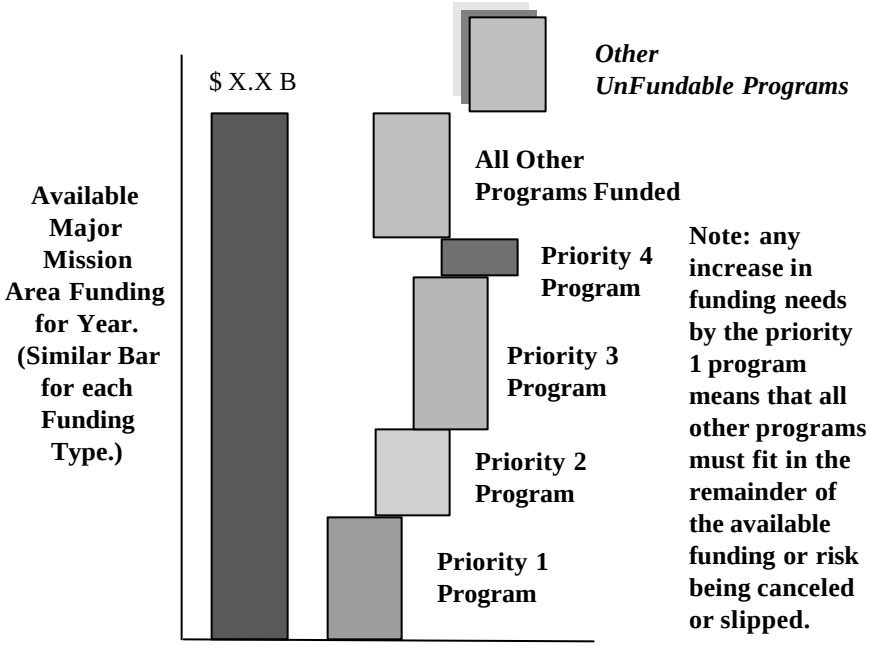
# DoD Economics



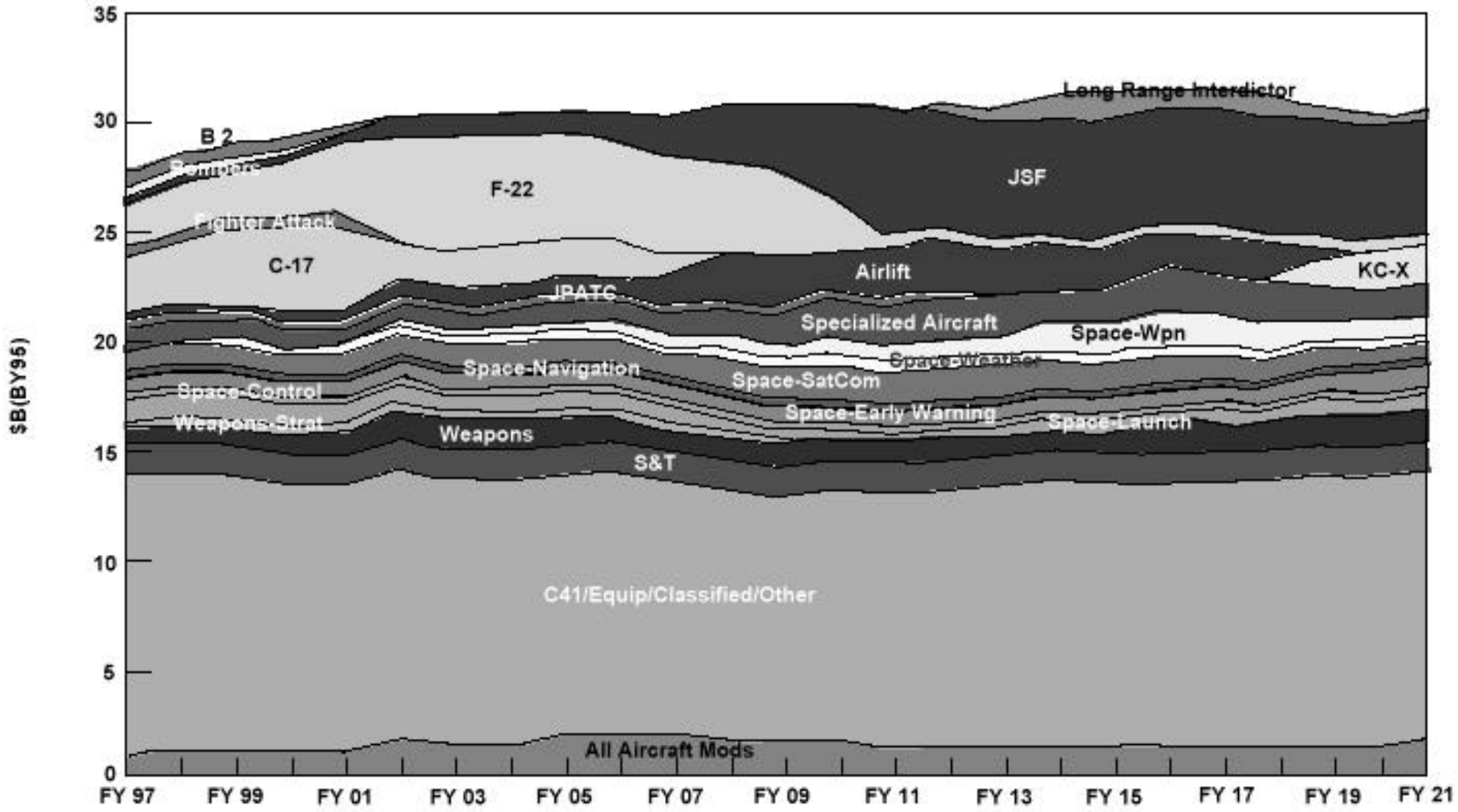

**Investments BY Service (Constant FY96 Dollars) (FY96 Projections)**




| Fiscal Year 2000 Department of Defense Appropriation | | | | | |
|---|---|---|---|---|---|
| | ARMY | Air Force | Navy | Def. Wide | Total |
| RDT&E | 4.4 | 13.1 | 8.0 | 8.9 | 34.4 |
| Procurement | 9.7 | 19.2 | 22.0 | 2.1 | 53.0 |
| Mil. Personnel | 28.8 | 20.9 | 26.6 | | 76.3 |
| O&M | 23.0 | 25.2 | 25.8 | 24.8 | 98.8 |
| Other | 1.8 | 1.1 | 1.3 | 1.2 | 5.5 |
| TOTAL | 67.7 | 79.5 | 83.7 | 37.0 | 268.0 |
| Note: RDT&E + Procurement = Acquisition or Investment | | | | | |
| Other = Mil. Construction, Family Housing, Funds and Other. | | | | | |



# Air Force Mission Area Planning Projection

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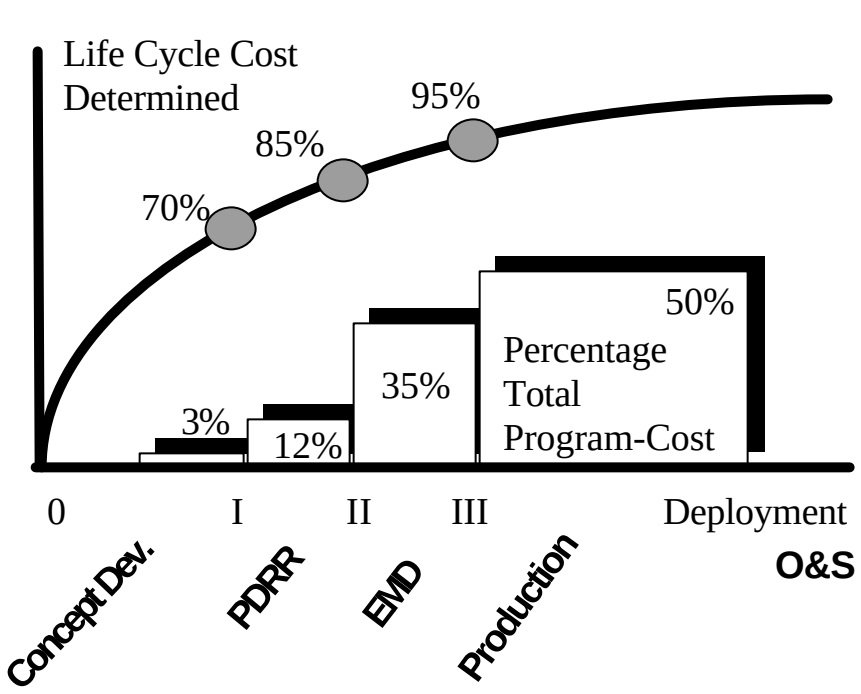
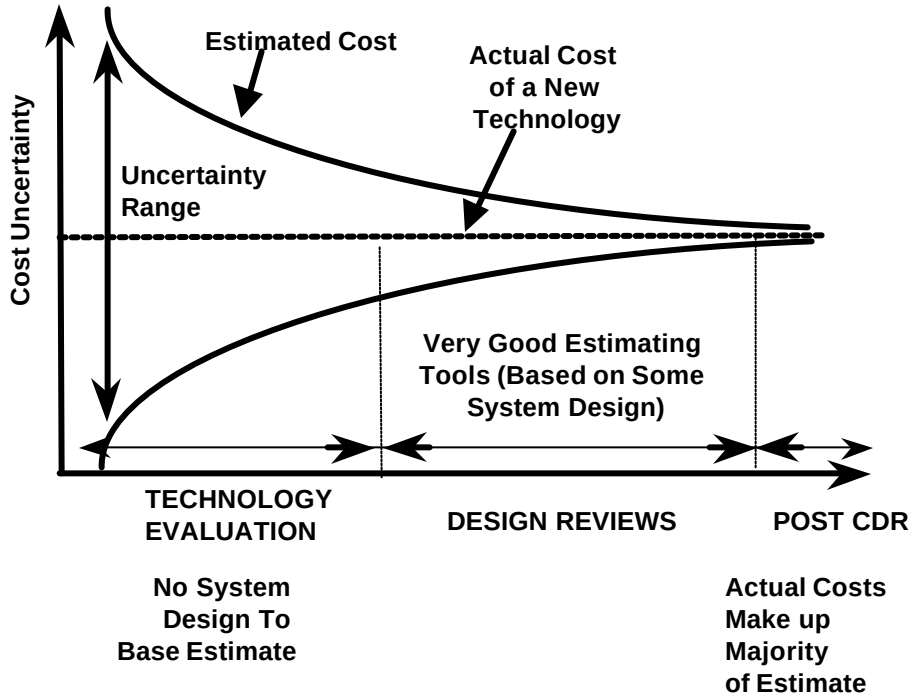
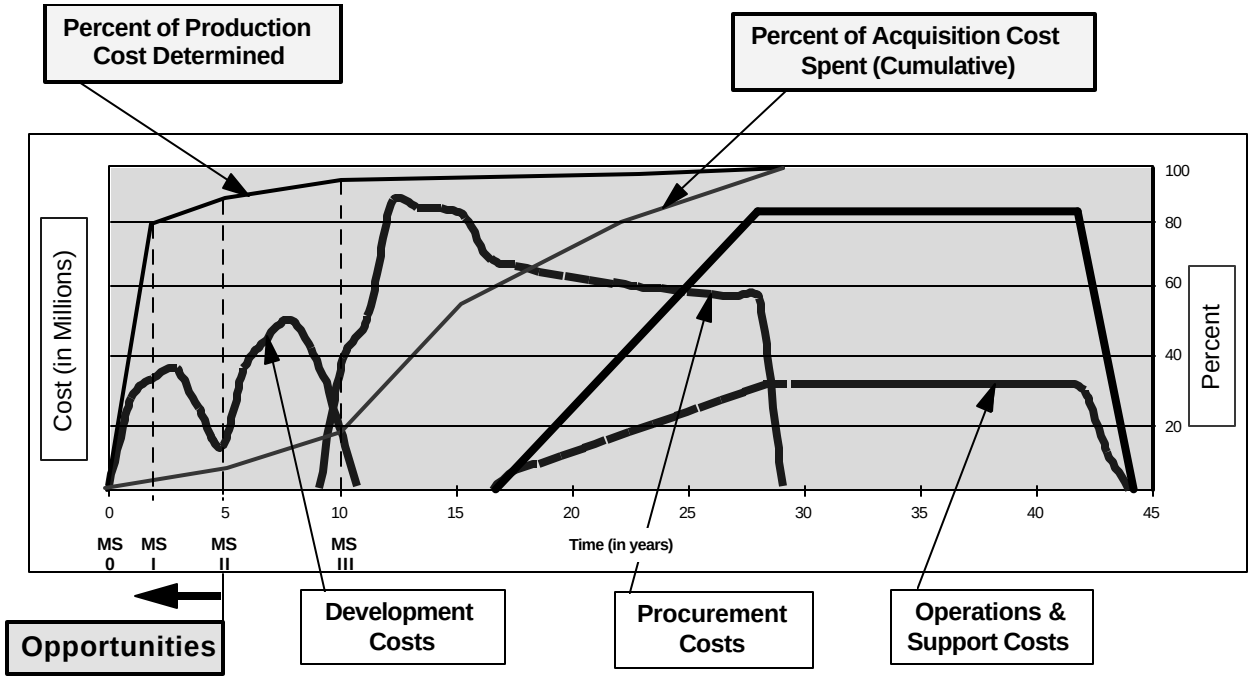
# COST ESTIMATE UNCERTAINTY



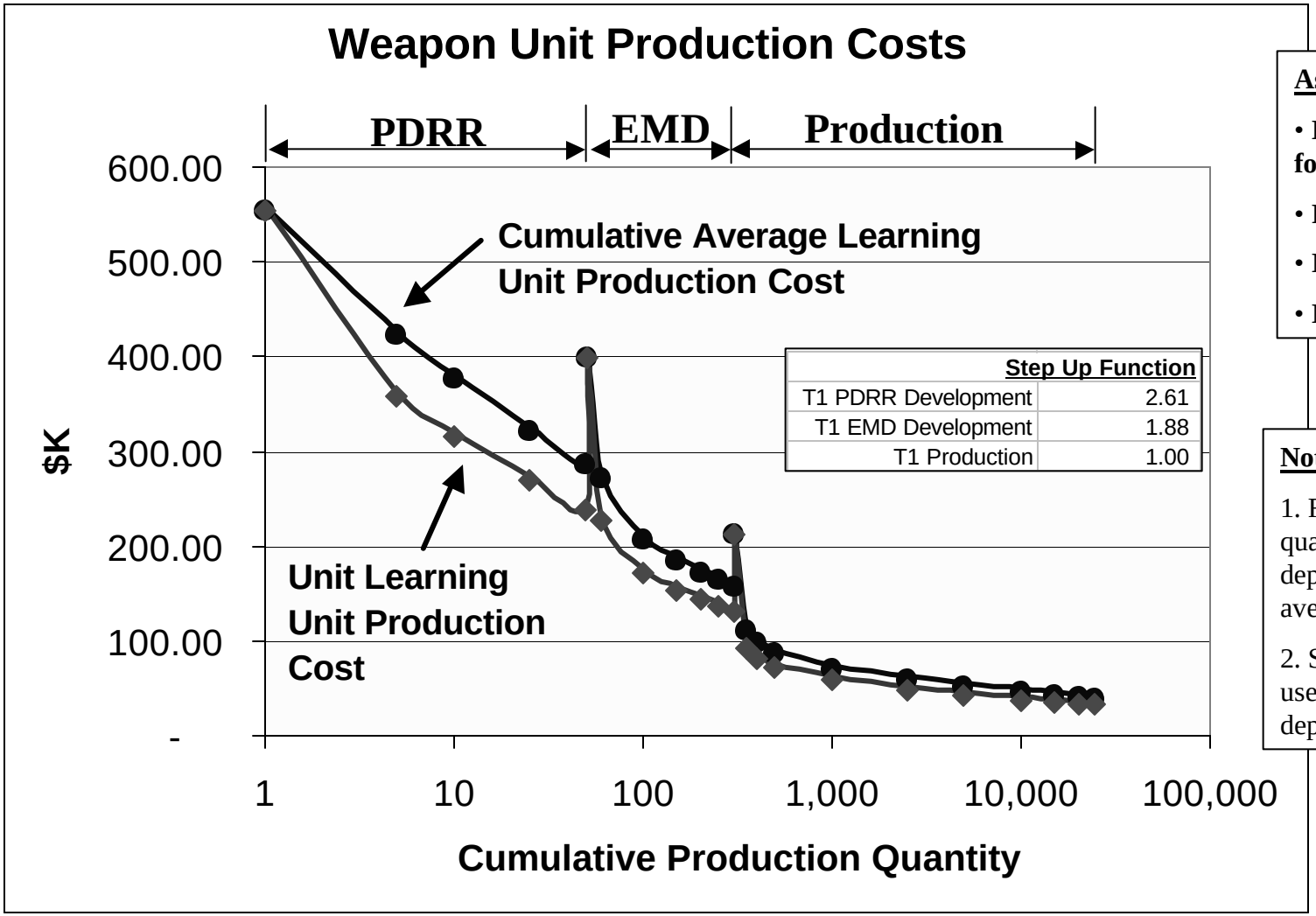
# Missile Cost History




**Typical O&S**
- Weapon
- Platform

| | CASE 1 (Aircraft) | | CASE 2 (Weapon) | |
|---|---|---|---|---|
| | % | $ B | % | $ B |
| RDT&E | 6 | 10.4 | 15 | 0.2 |
| Production | 54 | 93.2 | 76 | 1.2 |
| O&S | 40 | 69 | 9 | 0.2 |

# Unit Learning - Sample



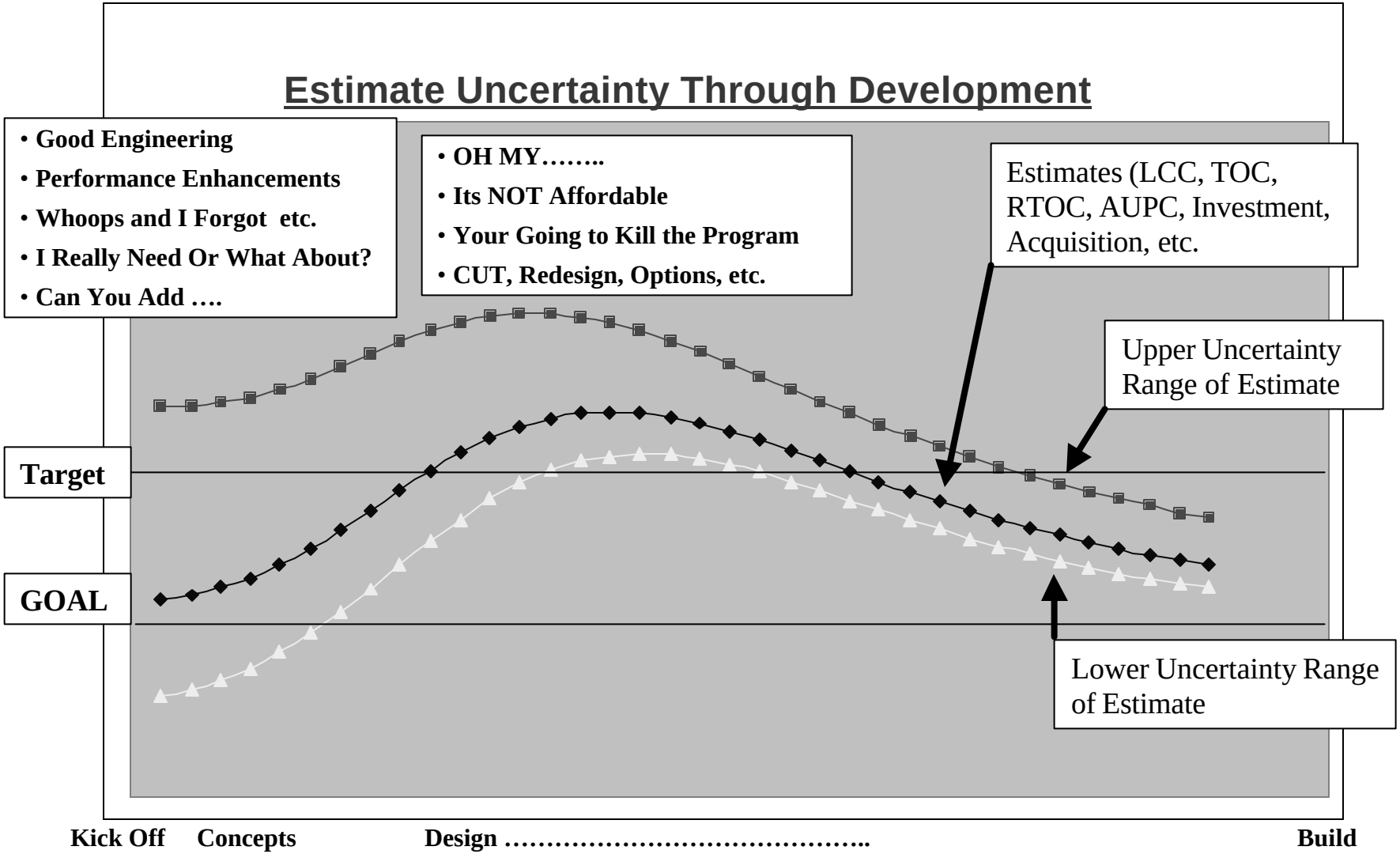

**Assumption:**

- **Learning vs.. Lot Costs for Development**
- **Recurring Costs Only**
- **Normal 3 Phase Program**
- **No Significant Redesign**

**Notes:**

1. For larger development quantities, quantity dependent learning vs. lot average costs are observed.
2. Step-up-functions are useable and are quantity dependent.

# Understand Programs & Estimates Change




**Typical Cost Estimating History Traced over Development of A Program**

# Estimating/Modeling "Usefulness" By Phase

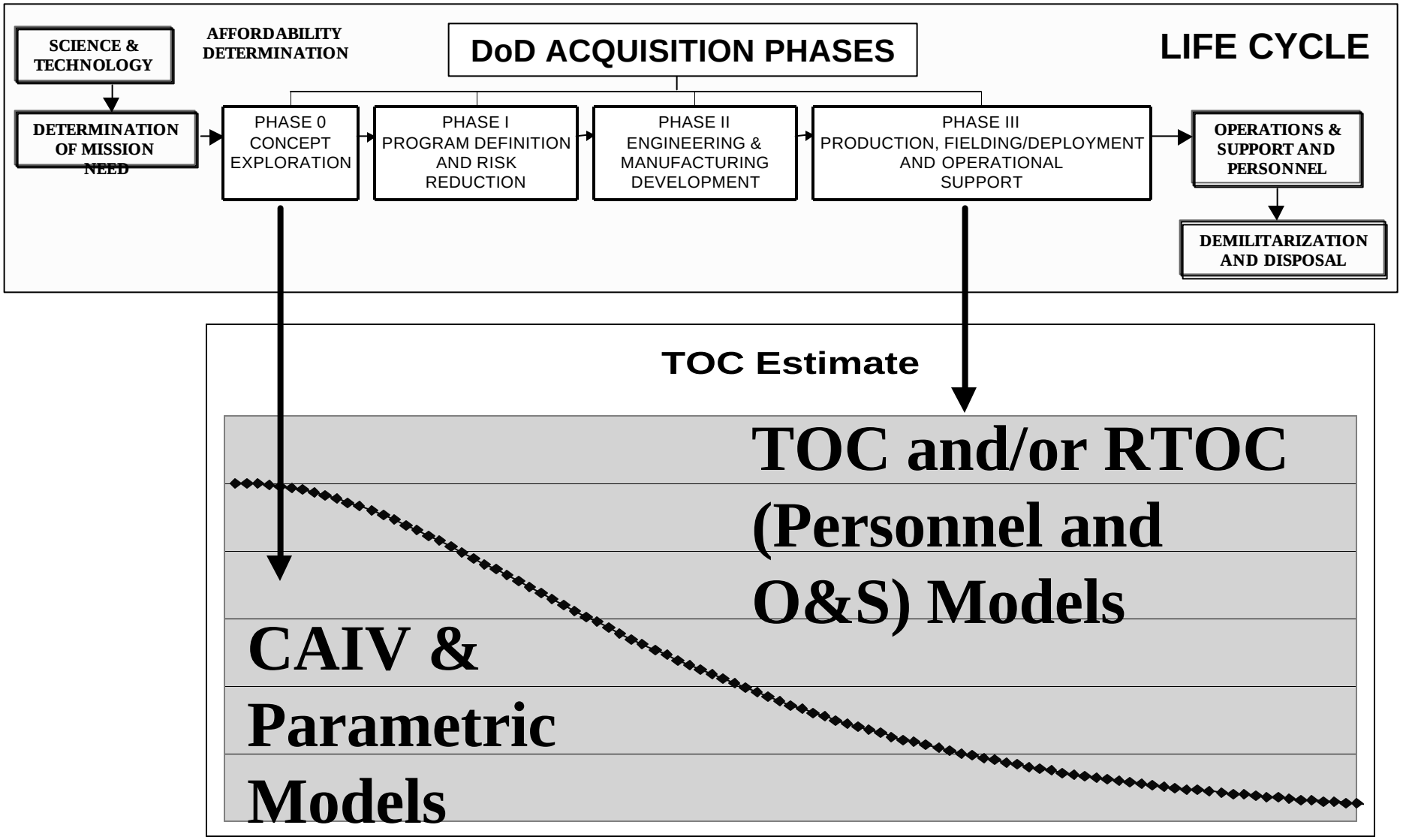
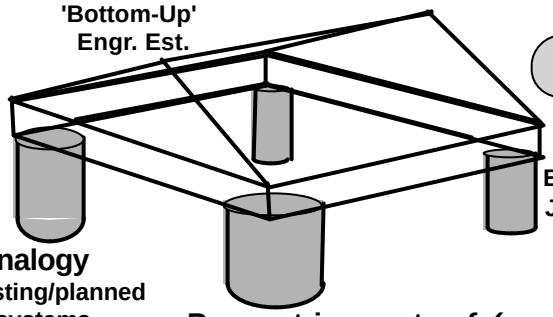



**Chart Similar to that Presented by Col. Scoop Cooper (Dir. AF R-TOC) at ISPA BoD Meeting 21 January 2000 @ Tucson, Az.**

# Parametric Cost Models Span System Fidelity and LCC Phases




*Four "Pillars" of Cost Analysis*

**Parametric: cost = *f (system characteristics)*** — **aka Cost Estimating Relationships (CERs)**

| Model Level | Example | Cost Models | Cost Data Bases |
|---|---|---|---|
| Multi-Mission | Air-to-Air & Air-to-Ground | *Aggregation of lower level Cost Elements, usually via Spreadsheet Model* | |
| Mission Level | Air-to-Ground | | |
| System Level | F-15E | PRICE / SEER; Korda Eng; Mgmt Resrch; Services; Software; ASP CCA + Other Internal | Services; Industry; Raytheon |
| Segment Level | Radar | | |
| Subsystem Level | Signal Processor | | |
| **LCC Phase** | | | |
| R&D | | ● ● ● ● ● | ● ● ● |
| Procurement | | ● ● ● ● ● | ● ● ● |
| O&S | | ● ● ● ● | ● ● |

**Parametric Model Types - Cost is a:**

- **Function of Physical Characteristic** — **- Example $ = ¦(Weight & Complexity)**
- **Function of # of Statements** — **- Example $ = ¦(Lines) * $/hr.**
- **Function of Similar To Item** — **- Example $ = ¦(Similar Item & Complexity Delta)**
- **Function of Performance** — **- Example $ = ¦(Thrust & Temperature)**

# Cost Models - Types

| **Types** | **Applicability** |
|---|---|
| A. Vendor Quotes & Manufacturing Estimates | Product is ready to build or design is nearly complete |
| B. Sim-To (Similar to an existing product)<br>$\$_N = \$_{old} * Cmplx_N/Cmplx_{old}$ | When ever a "close" Sim-To exists and data is complete |
| C. Cost is a function of Physical Characteristics<br>$\$_N = f(a*WT^{(b*Cmplx)})$<br>(Examples - PRICE H & SEER) | When design solution set is complete enough for physical characteristics to be determinable |
| D. Cost is a function of Performance & Technology<br>$\$_N = f$[(perf. Char.) & Technology]<br>(Example - Radar Range vs. Cost) | Conceptual tradeoffs - Evaluating desirements vs. available budgets. |

# PROGRAM COST MODELING CHANGES BY PHASE OVER A PROGRAM LIFE CYCLE

| Cost Analysis and LCC Phase | | | | | Risk |
|---|---|---|---|---|---|
| Model | RDT&E | Investment | O&S | Disposal | Analysis |
| PRICE | ☆ | ☆ | ☆ | | |
| SEER | ☆ | ☆ | ☆ | | |
| ACE-IT | ☆ | ☆ | ☆ | ☆ | ☆ |
| Crystal Ball | | | | | ☆ |
| CASA | | | ☆ | | |
| CORE | | | ☆ | | |

# Example: $= ¦(Performance)

## Radar Range Model

| | | | |
|---|---|---|---|
| Year of Estimate | **1999** | Years to Escl | 14 |
| Year of Model | **1985** | Escl / year | 1.035 |
| Range to target (max. Km) | 56 | Escl. Factor | 1.619 |
| Target Cross Sectional Area (sq. m) | 0.01 | | |
| Learning Curve (factor) | 0.95 | Model calibrated on .95 learning curve | |
| Quantity of radars procured | 94 | Qty Factor | 1.0575 |
| Procurement Overhead Factor (This is for the PMO, Data, Logistics | 1.0 | | |
| | | | |
| Development Cost (M$) | **424.97** | Air Force Avionics Lab Study | |
| Unit Average Cost (M$) (model tailored for 200 units. Cost show is | **19.70** | Ground Radar Study | |
| Unit O&S Cost (M$ and 20 yr O&S) | **14.31** | Ground Radar Study | |
| Total Procurement (M$) | **1,852.08** | | |
| Total O&S (M$ and 20 yr O$S) | **1,344.85** | | |

**Ground Based Radar Average Unit Cost in FY85 M $ at Quantity of 200 units is**

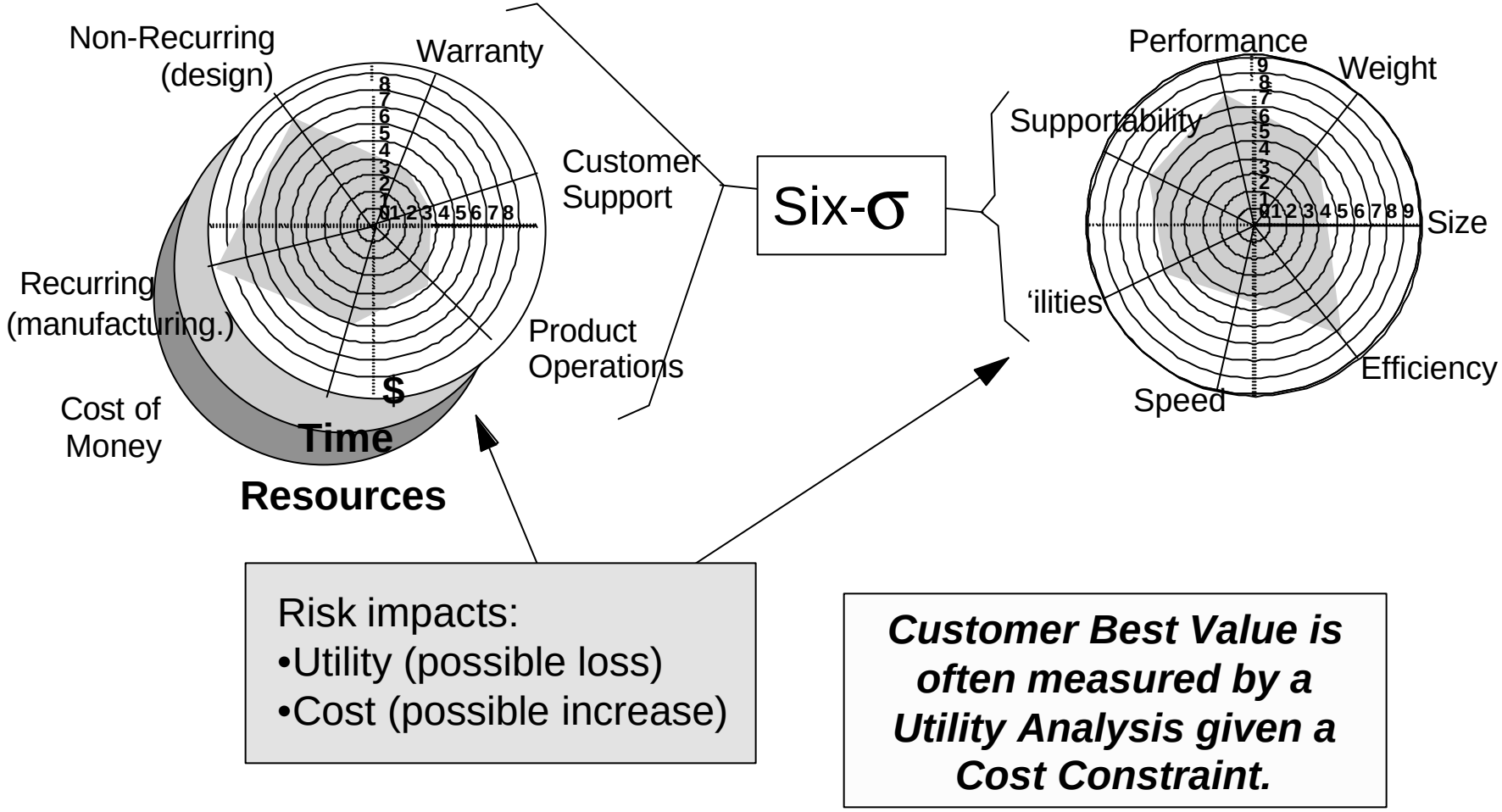
**= [0.065 * (Range/{Target Cross Sectional Area}^(1/4))]**

# Models Intro. #1

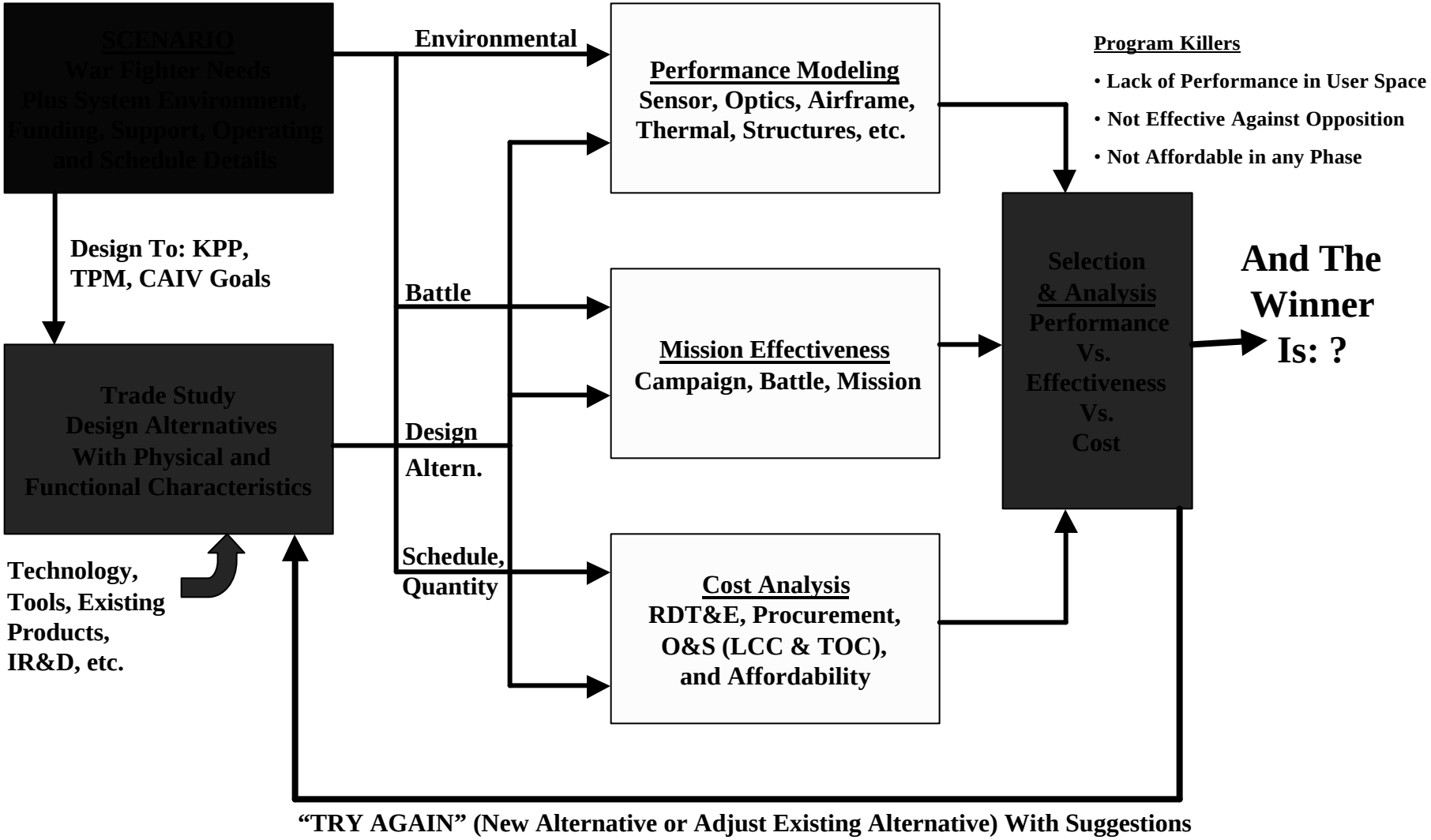
# Models Intro. #2

## ASPECTS OF COST

## ASPECTS OF UTILITY

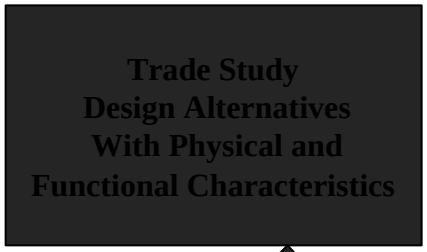


# CAIV DECISION POINT
# Selection of the "Best Value" Alternative



# CAIV DECISION POINT

# Software is included in the "Best Value" Alternative




Technology, Tools, Existing Products, IR&D, etc.

## Missile Alternative Example

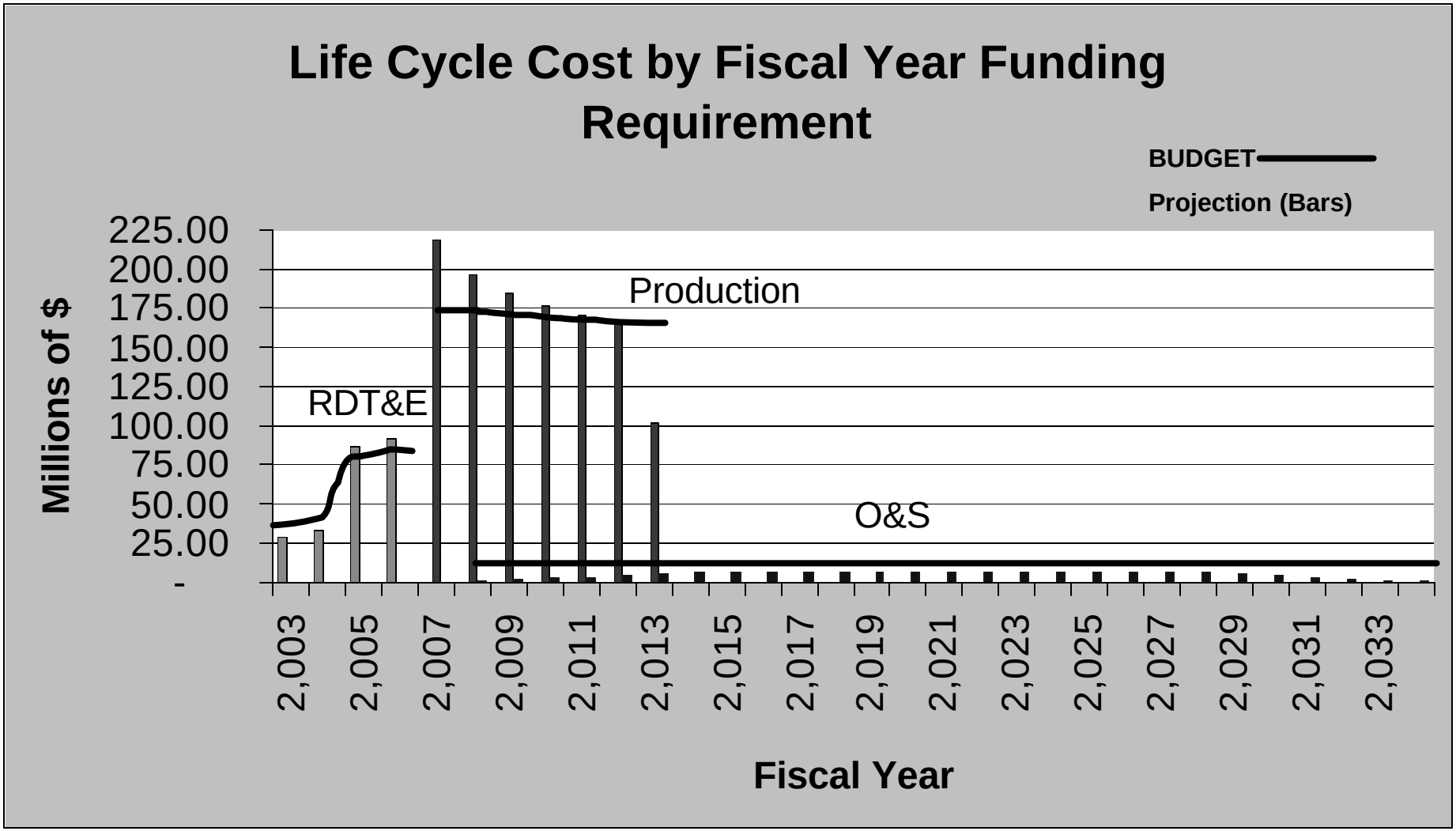
- Physical and Functional Characteristics
  - Size, Weight, Speed, Range, Payload, etc.
  - Functions Performed (Search, Ballistic Load, etc.)
    - Hardware Resident
      - Seeker Head
      - Propulsion, Warhead, etc.
    - Software Resident
      - Target ID, Tracker, etc.
    - HW/SW Combined
      - Position in Space (IMU and GPS)

**Software**

- Functions Performed
  - Lines of code (Size)
  - Interfaces
- Coding Group Capabilities
- Environment
- Schedule

# AFFORDABILITY EXAMPLE

## Program Planning for "Affordable Value"



# Acquisition Sample Problem – Initial Estimate

| *Initial Estimate* | $ M | *Phase* Quantity | Years | $/Year |
|---|---|---|---|---|
| ***Development*** | 250.0 | | | |
| ***PDRR*** | 80.0 | | 2 | 40.0 |
| ***EMD*** | 170.0 | | 3 | 56.7 |
| ***Procurement*** | 1,200.0 | | 7 | **171.4** |
| ***Unit Procurement*** | **0.048** | **25,000** | | |
| ***O&M + Personnel*** | 250.0 | | 20 | 12.5 |
| ***TOTAL LCC (TOC)*** | 1,700.0 | | | |

**Problem: Weapon discussed on prior charts has a procurement cost per year that exceeds the budgeted value of $110 Million per year.**

- **Preferred Solution: CAIV (65% Unit cost reduction) and or Facilities Planning**
- **Usual Solution: Business Practice with no redesign or Facilities Planning**

# Acquisition Sample Problem Continued

## Business Solution: One Half the Quantity Estimate

| *Reduced Quantity Estimate* | *Procurement* | | *Phase* | |
|---|---|---|---|---|
| | **$ M** | **Quantity** | **Years** | **$/Year** |
| ***Development*** | 250.0 | | | |
| ***PDRR*** | 80.0 | | 2 | 40.0 |
| ***EMD*** | 170.0 | | 3 | 56.7 |
| ***Procurement*** | 766.7 | | 7 | **109.5** |
| ***Unit Procurement*** | **0.061** | **12,500** | | |
| ***O&M + Personnel*** | 250.0 | | 20 | 12.5 |
| ***TOTAL LCC (TOC)*** | 1,266.7 | | | |

**Acquisition Sample Problem – Results of Quantity Change**

| *Changes - From Initial to Reduced Quantity Estimates* | |
|---|---|
| ***Unit Procurement*** | 128% |
| ***Total LCC*** | 75% |
| ***Quantity Change*** | 50% |
| ***Procurement Yearly Total*** | 64% |

**LCC for Acquisition of 2X the One Half Quantity Solution (required quantity of 25,000) is 150% of Original Estimate for same quantity. (SAR Problem!)**

**Its Solutions Like This That Causes Congress To Cancel Programs**

# Acquisition Sample Problem Solution

**1st. Identify System Affordability Constraints Early**

- **Set TOC and Acquisition Cost Goals**
- **Work with Customer and Establish Real Schedule**

**2nd. Design Systems Using CAIV and/or DTLCC**

- **Evaluate Kpp vs Cost**
- **Customer Involvement**
- **Schedule vs Quantity for Best Unit Cost**
- **TOC or RTOC or LCC Goals**

**3rd. Review Often With Customer Involvement**

- **Continually Work Problem**


AND THE
WINNING
OPTION IS: